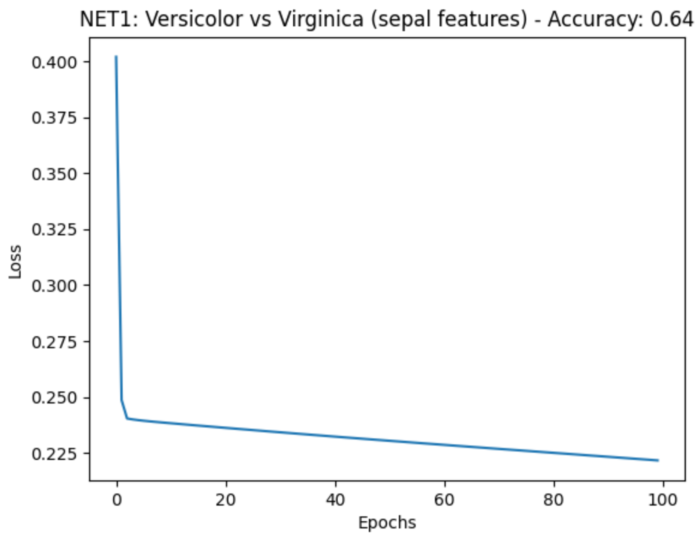
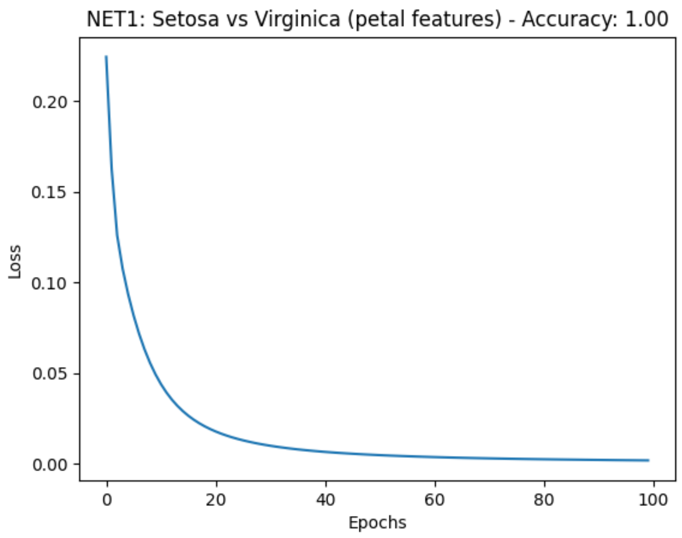
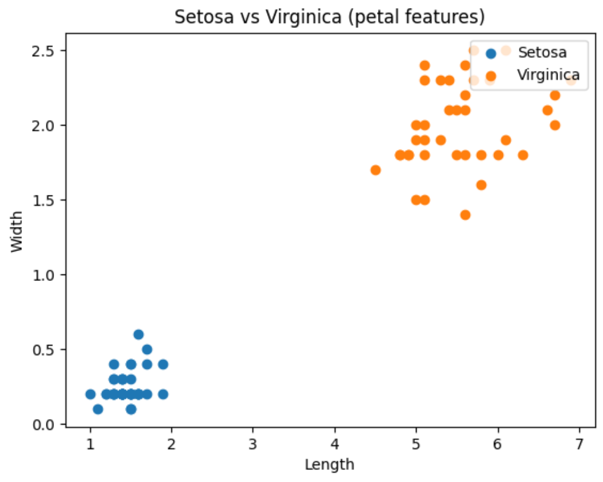
HW 6 Report: Neural Networks

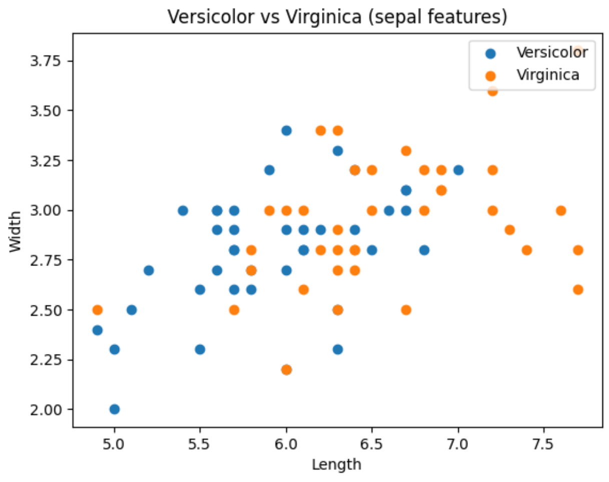
NET 1





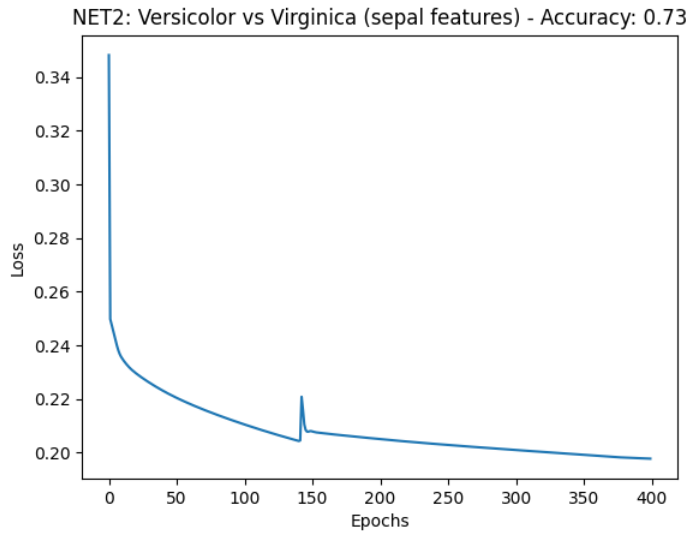
For NET1, we can see that classifying Versicolor vs Virginica using sepal features results in a much lower accuracy compared to classifying Setosa vs Virginica using petal features. The hidden layer cannot learn the complexity of the relationship between Versicolor vs Virginica.

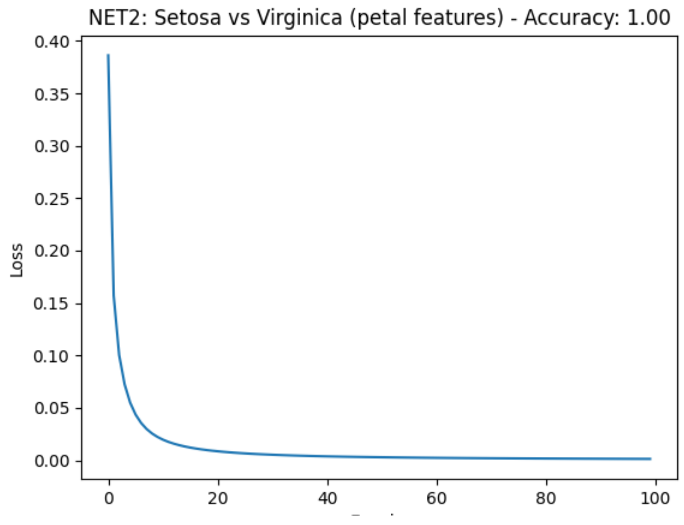


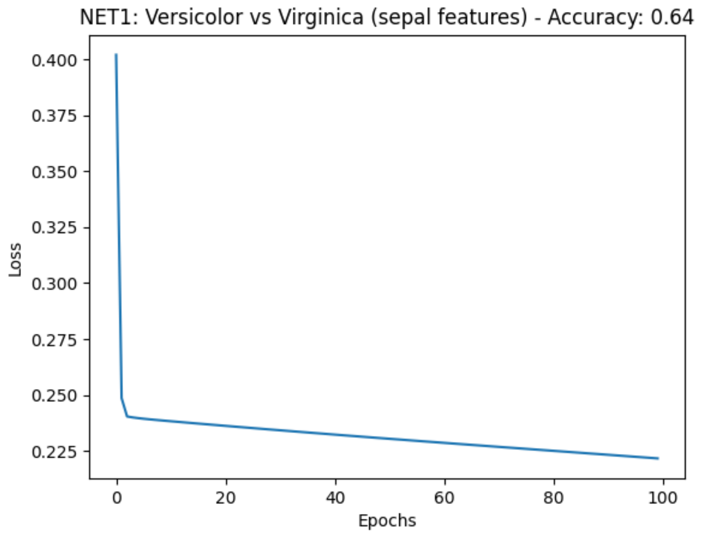


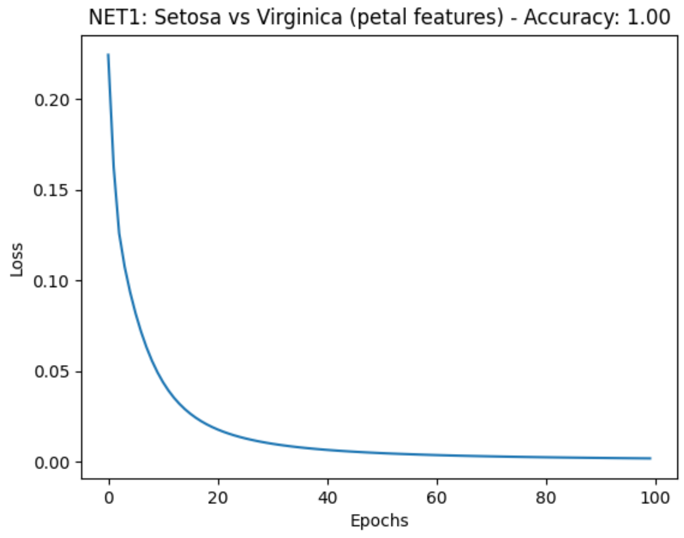
From these plots, it is clear the Setosa vs Virginica data points can be linearly separated, while Versicolor vs Virginica cannot. This is the core reason that the accuracy in the first set is much lower. To solve this, we could increase the number of layers so that the model may learn any non-linear relationships.

NET 2



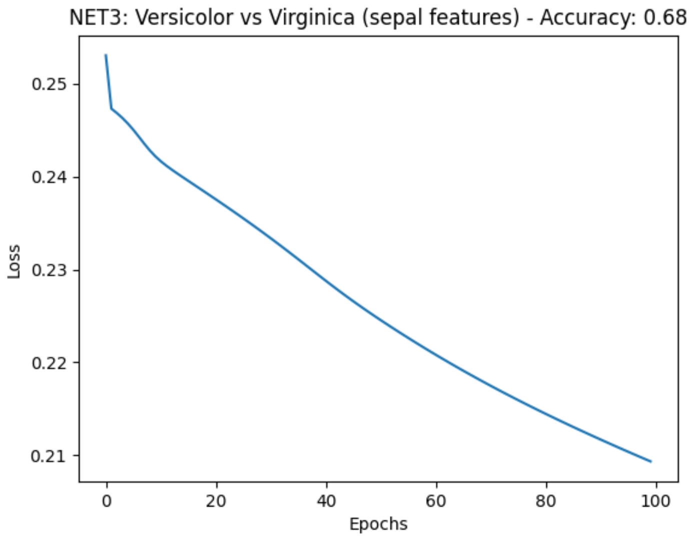


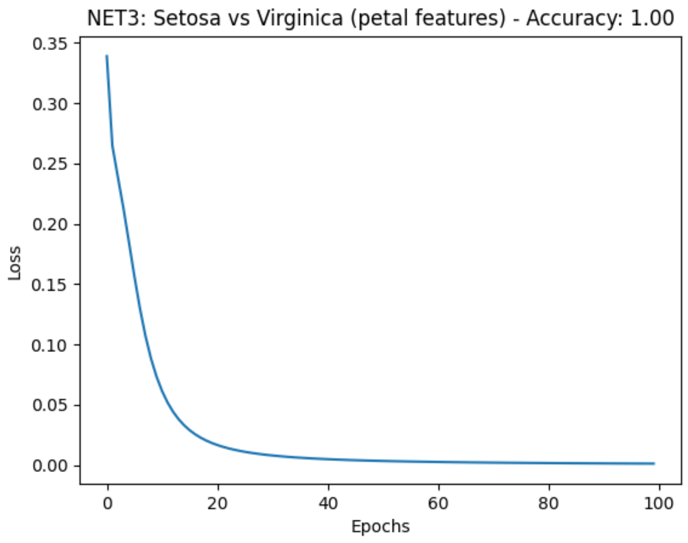


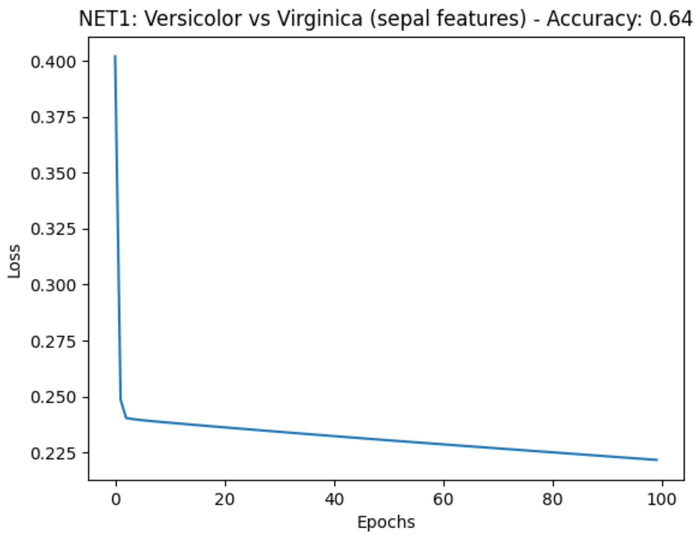


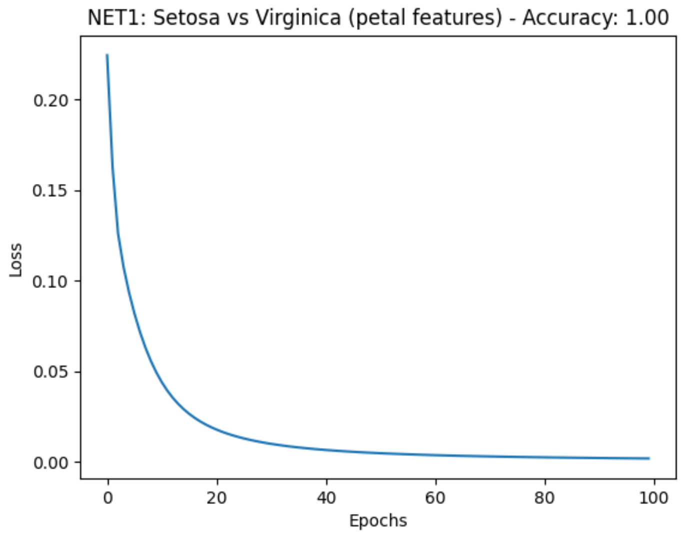
Increasing the number of neurons in a layer can allow the model to learn more complicated relationships. In set 1 increasing the number of neurons from 5 to 20 resulted in a 9% more accurate model. Because of set 2's simple relationship, NET2 still has no trouble classifying the Setosas from Virginicas.

NET 3



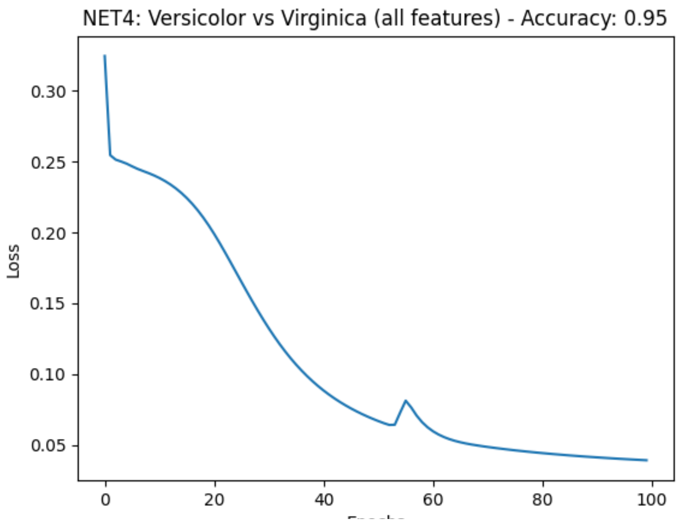


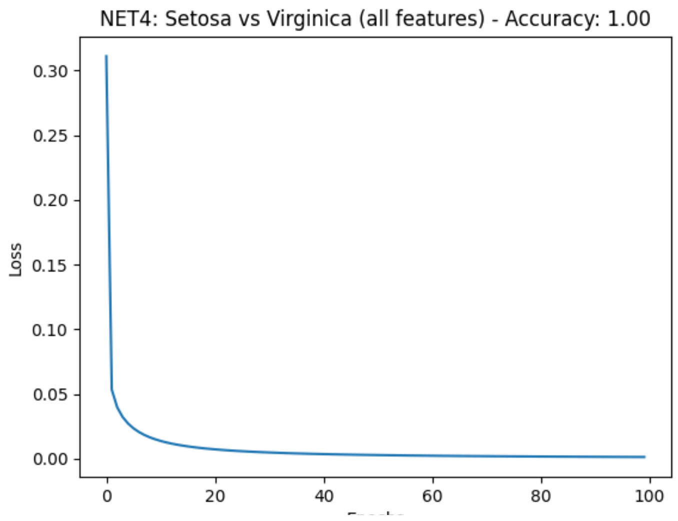


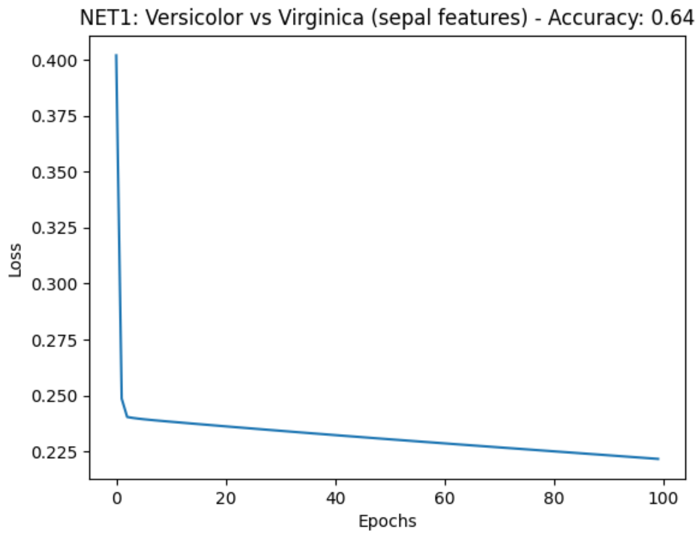


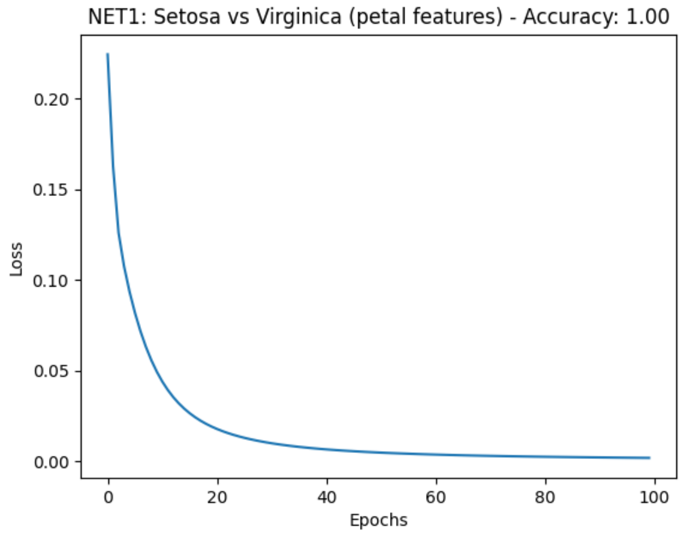
Adding a layer to NET1 resulted in a 4% increase in accuracy on set 1. A 4% increase is not substantial and could likely be to a slightly better train-test-split. This means adding 1 extra layer had little to no effect on the accuracy for set 1. Classifying Versicolors vs Virginicas using sepal features may be too complicated 2 hidden layers. It is possible that using more hidden layers, along with increasing the number of neurons per layer could result in greater accuracy; however, this could also easily lead to overfitting reducing the accuracy of the model.

NET 4









Utilizing all 4 features enables the model to successfully classify Versicolors vs Virigincas. Up until NET4, the model had little success classifying set 1 using sepal features. This leads me to believe there is either not enough data provided or there is no way to draw a distinction between the two classes using sepal width and length. Introducing pedal features enables the model to finally find a pattern that correctly predicts the data.

Full Code Implementation

```python
import numpy as np
import pandas as pd
from typing import Tuple
import matplotlib.pyplot as plt
from sklearn import datasets
from sklearn.model_selection import train_test_split

# read_data, get_df_shape, data_split are the same as HW3
def read_data(filename: str) -> pd.DataFrame:
    d = pd.read_csv(filename)
    df = pd.DataFrame(data=d)
    return df

def extract(df: pd.DataFrame, class1, class2, feat1, feat2) -> Tuple[pd.DataFrame,
pd.Series]:
    filtered_df = df[df['variety'].isin([class1, class2])]
    features = filtered_df[[feat1, feat2]]
    labels = filtered_df['variety'].map({class1: 0, class2: 1})
    return features, labels

def extract_all_feat(df: pd.DataFrame, class1, class2) -> Tuple[pd.DataFrame,
pd.Series]:
    filtered_df = df[df['variety'].isin([class1, class2])]
    features = filtered_df.drop('variety', axis=1)
    labels = filtered_df['variety'].map({class1: 0, class2: 1})
    return features, labels

def sigmoid(z):
    return 1 / (1 + np.exp(-z))

def function_derivative(z):
    fd = sigmoid(z)
    return fd * (1 - fd)


class NN:
    def __init__(self, features, hidden_layers, output_neurons, learning_rate):
        self.features = features
        self.hidden_layers = hidden_layers
        self.output_neurons = output_neurons
        self.learning_rate = learning_rate

        # initialize weights
        self.W = []
        self.b = []
        layer_sizes = [features] + hidden_layers + [output_neurons]
        for i in range(len(layer_sizes) - 1):
            self.W.append(np.random.randn(layer_sizes[i], layer_sizes[i+1]))
            self.b.append(np.zeros(layer_sizes[i+1]))

    def train(self, X, t, epochs=1000):
        costs = []
        for epoch in range(epochs):
            # forward pass
            nets, activations = self.forwardPass(X)

            # backpropagation
            self.backpropagate(t, nets, activations)

            # find the cost function
            if epoch % 10 == 0:
                loss = np.square(np.subtract(t, activations[-1])).mean()
                costs.append(loss)

        return costs

    def forwardPass(self, X):
        X = np.array(X)
        nets = []
        activations = [X]

        a = X
        for i in range(len(self.W)):
            z = a.dot(self.W[i]) + self.b[i]
            a = sigmoid(z)
            nets.append(z)
            activations.append(a)

        return nets, activations

    def backpropagate(self, t, nets, activations):
        t = np.array(t)
        deltas = [None] * len(self.W)
        deltas[-1] = (activations[-1] - t) * function_derivative(nets[-1])

        for i in reversed(range(len(self.W) - 1)):
            deltas[i] = function_derivative(nets[i]) * deltas[i+1].dot(self.W[i+1].T)

        for i in range(len(self.W)):
            d_W = activations[i].T.dot(deltas[i])
            d_b = np.sum(deltas[i], axis=0)

            self.W[i] -= self.learning_rate * d_W
            self.b[i] -= self.learning_rate * d_b


    def predict(self, X):
        a = X
        for i in range(len(self.W)):
            z = a.dot(self.W[i]) + self.b[i]
            a = sigmoid(z)

        return (a > 0.5).astype(int)


def NET(set, test, hidden_layers, title=""):
    nn = NN(features=set[0].shape[1], hidden_layers=hidden_layers, output_neurons=1, 
learning_rate=0.01)
    cost = nn.train(set[0], set[1])

    y_pred = nn.predict(test[0])
    acc = accuracy(test[1], y_pred)
    print(f"{title} - Accuracy: {acc:.2f}")

    plt.plot(cost)
    plt.title(f"{title} - Accuracy: {acc:.2f}")
    plt.ylabel("Loss")
    plt.xlabel("Epochs")
    plt.show()


def visualizeData(X, y, title, classes):
    X = X.values
    y = y.flatten()

    for label, class_name in zip(np.unique(y), classes):
        idx = y == label
        plt.scatter(X[idx, 0], X[idx, 1], label=class_name)

    plt.title(title)
    plt.ylabel('Width')
    plt.xlabel('Length')
    plt.legend(loc="upper right")
    plt.show()


if __name__ == "__main__":
    def accuracy(t, y_pred):
        accuracy = np.sum(np.array(t) == np.array(y_pred)) / len(t)
        return accuracy
    train_df = read_data("./iris_training_data.csv")
    test_df = read_data("./iris_testing_data.csv")

    X1, t1 = extract(train_df, 'Versicolor', 'Virginica', 'sepal.length',
'sepal.width')
    X1_test, t1_test = extract(test_df, 'Versicolor', 'Virginica', 'sepal.length',
'sepal.width')

    X2, t2 = extract(train_df, 'Setosa', 'Virginica', 'petal.length', 'petal.width')
    X2_test, t2_test = extract(test_df, 'Setosa', 'Virginica', 'petal.length',
'petal.width')

    t1 = t1.values.reshape([len(t1),1])
    t2 = t2.values.reshape([len(t2),1])
    t1_test = t1_test.values.reshape([len(t1_test),1])
    t2_test = t2_test.values.reshape([len(t2_test),1])

    set1 = (X1, t1)
    set2 = (X2, t2)
    set1_test = (X1_test, t1_test)
    set2_test = (X2_test, t2_test)

    X3, t3 = extract_all_feat(train_df, 'Versicolor', 'Virginica')
    X3_test, t3_test = extract_all_feat(test_df, 'Versicolor', 'Virginica')

    X4, t4 = extract_all_feat(train_df, 'Setosa', 'Virginica')
    X4_test, t4_test = extract_all_feat(test_df, 'Setosa', 'Virginica')

    t3 = t3.values.reshape([-1, 1])
    t4 = t4.values.reshape([-1, 1])
    t3_test = t3_test.values.reshape([-1, 1])
    t4_test = t4_test.values.reshape([-1, 1])

    set3 = (X3, t3)
    set4 = (X4, t4)
    set3_test = (X3_test, t3_test)
    set4_test = (X4_test, t4_test)

    visualizeData(X1, t1, "Versicolor vs Virginica (sepal features)", ("Versicolor",
"Virginica"))
    visualizeData(X2, t2, "Setosa vs Virginica (petal features)", ("Setosa",
"Virginica"))

    # NET 1
    NET(set1, set1_test, hidden_layers=[5], title="NET1: Versicolor vs Virginica
(sepal features)")
    NET(set2, set2_test, hidden_layers=[5], title="NET1: Setosa vs Virginica (petal
features)")
```

```
    # NET 2
    NET(set1, set1_test, hidden_layers=[20], title="NET2: Versicolor vs Virginica (sepal features)")
    NET(set2, set2_test, hidden_layers=[20], title="NET2: Setosa vs Virginica (petal features)")

    # NET 3
    NET(set1, set1_test, hidden_layers=[20], title="NET3: Versicolor vs Virginica (sepal features)")
    NET(set2, set2_test, hidden_layers=[10, 5], title="NET3: Setosa vs Virginica (petal features)")

    # NET 4
    NET(set3, set3_test, hidden_layers=[5], title="NET4: Versicolor vs Virginica (all features)")
    NET(set4, set4_test, hidden_layers=[5], title="NET4: Setosa vs Virginica (all features)")
```